Attention BCI – project summary

The ability to selectively pay attention to a particular stream of input in the environment and to ignore competing irrelevant sounds is of utmost importance in daily life. Yet, to date much remains unknown about the neural basis underlying this important capacity. Moreover, performance on this important cognitive task varies greatly across individuals and under different environmental conditions, and attention is also known to 'wander' and fluctuate over time.

The broad objective of this project is to link neural activity to behavioral performance on challenging selective attention tasks, and to understanding the factors underlying variability in selective attention performance across individuals. Using non-invasive neurophysiological recordings in humans, I will test the hypothesis that top-down modulation of sensory processing is directly linked to selective attention performance and can explain variability in performance across individuals, stimulus-conditions and over time.

During this four-year project we have made substantial progress towards addressing the key research questions put forth for this project. Specifically, behavioral and neural data has been collected from >150 individuals on a variety of Selective Attention tasks, in which we parametrically changed task difficulty along different stimulus dimensions. The results have been extremely informative as to which factors make stimuli easier/hard to pay attention to in a noisy environment, as well as the neural mechanisms involved in successfully attending to one source and overcoming distraction.

The main results obtained under the current research are:

1. **The centrality of rhythm for selective attention.**
   In a series of studies we consistently find that selective attention is substantially improved for rhythmic vs. non rhythmic stimuli. These results highlight an important role for temporal predictability in focusing attention, in line with the Attention to Time hypothesis.

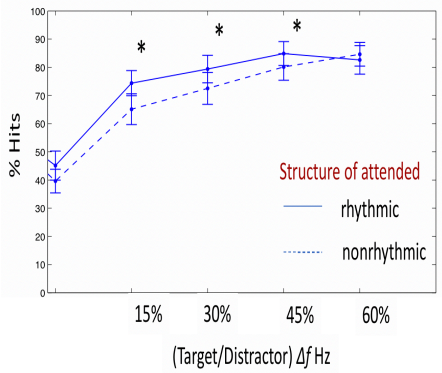

Figure 1. Performance on a challenging attentional task is facilitated when stimuli are presented in a Rhythmic (full line), vs. Non-rhythmic structure (dotted)

2. **Temporal predictions are helpful in ignoring as well as attending.** We find that not only do temporal predictions assist in focusing attention toward task-relevant sounds, but that it is also easier to *ignore* sounds that are temporally predictable. This strengthens the notion that both attending and ignoring are *active* processes, that (among other things) utilize the statistics of the stimuli to selectively enhance or suppress their neural representation and promote behavioral goals.

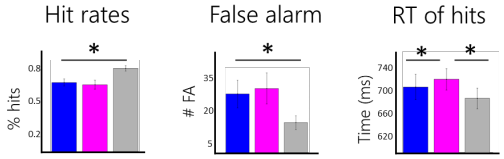

Figure 2. Modulation of behavioral performance (hit rates, RT of hit trials and false alarm rates) by different Distraction Types: Rhythmic (blue), Non-rhythmic (magenta) and No distraction (gray). In all cases the No distraction condition yielded better behavioral results than both distraction types. RT was less disrupted by Rhythmic compared to Non-rhythmic distractor.

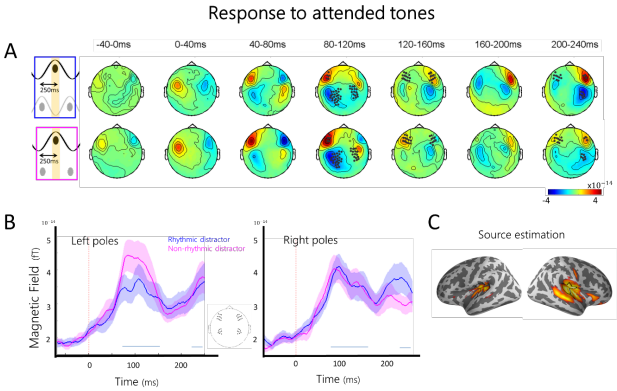

Figure 3. Neural response locked to the presentation of **attended tones** (A) Topographies in time windows of 40 ms present the dynamics of the neural response under Rhythmic (top) and Non-rhythmic (bottom) distraction. Black dots inside the topographies denote MEG sensors in which there was a significant difference in activation between distraction types. (B) Absolute ERFs evoked by attended tones under Rhythmic (blue) and Non-rhythmic (pink) distraction, recorded over left and right predefined poles of activation. (C) The estimated source of MEG recorded activity in response to attended tones (collapsed over both distraction conditions) maps onto auditory areas.

3. **The importance of space in allocating auditory attention is overestimated.** A primary feature used to dissociate and segregate between objects their spatial disparity. Indeed, spatial location is a key element for focusing attention in the visual domain. However, we find that this is not necessarily the case for auditory attention, and that spatial segregation in fact plays a minor role in auditory selective attention, even under severely adverse condition. This finding has implications both for understanding how auditory attention operates under natural conditions and which acoustic keys are utilized, as well as for the development of hearing assistive-devices, indicating that loss of spatial acuity should not necessarily impede performance.

4. **Sources of individual differences in attentional abilities.** Finally, a primary goal of the current project was to understand the factors contributing to individual differences in attentional performance. Our results confirm previous findings that personal cognitive capacity (as captured for example in variability in IQ and WM capacity) impact the ability to selectively attend to speech under adverse conditions. However, additionally our research indicate that individuals have the capacity to improve their own performance through training and lived experience. This holds great promise for the development and effectiveness of training-regimes for improving attentional abilities and performance at the individual level.

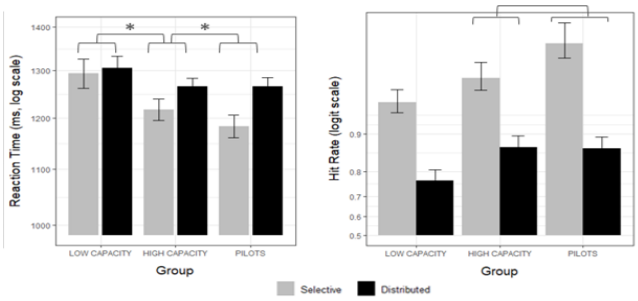

Figure 4. Performance on both Selective and Distributed attention tasks are enhanced in individuals with high cognitive capacity (IQ and WM). Performance on Selective attention is further enhanced by training, as reflected by improved performance in aircraft pilots vs. matched high-capacity controls.

Taken together, the results produced under this project offer a new broad understanding of the behavioral capacity and limitations of auditory selective attention, as well as the neural mechanisms and individual differences involved in this important faculty. Our research also provides specific directions for the development of training regimes and interfaces for improving attentional performance in individual participants. This endeavor holds much promise for improving the quality of life within specific populations – such as hearing impaired individuals and individuals with ADHD – as well as the general population at large.